Bulletin No. 91 1920

Agricultural Research Institute, Pusa

Notes on Practical Salt Land Reclamation

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1920

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VIEWS ON THE RECLAMATION STATION, DAULATPUR, SIND.

Notes on Practical Salt Land Reclamation.

[*Received for publication on 21st May, 1919.*]

CHAPTER I.

Alkali Land Reclamation.

THE question of alkali, *kalar*, *reh* or *usar* land has received a certain amount of attention in India from agricultural and irrigation authorities, but the subject is bound to force itself into greater prominence as modern perennial irrigation works extend.

Alkali land is so called when it contains a greater or less amount of water-soluble mineral salts which exert a harmful influence on vegetation. The question is often bound up with water-logging and leakage from irrigation canals.

Arid land all the world over, on which the annual rainfall is not sufficient to leach the soluble salt out of the surface soil, suffers from damage due to alkali.

The alkali damage is frequently not visible for some years after the opening of a new canal system, and then the water or want of silt is blamed.

While the chemical aspect of reclamation is of great importance, the practical technique is of still greater importance. This is frequently lost sight of in India, and where alkali problems crop up it is a mistake to consider that these can be solved solely by laboratory findings.

A brief survey of practical reclamation work in Egypt and India should be of value in order to give a definite idea of the most promising lines of work.

Without a soil survey it is impossible to state what area of land is affected in India. Sind is, however, probably in worse case than any other part of India, having an average annual rainfall of under 10 inches. In the Punjab the damage caused by alkali conditions is probably less and still less in the United Provinces.

CHAPTER II.*

Alkali Conditions in Sind.

In arid America, field parties of the Bureau of Soils have mapped the soil and studied the alkali conditions of a number of typical irrigated districts covering over 3,000,000 acres of land. They have found that on the average about 13 per cent. of the irrigated lands examined contain alkali in sufficient quantities to be either harmful to the growth of crops or to prevent entirely profitable cultivation. Sind has 30,000,000 acres, half of which are scheduled as cultivable and 4,000,000 are cultivated annually under irrigation. It is not possible to say what the per cent. is in Sind of alkali or *kalar* land without a proper soil survey, but it would probably be found not to be under the above percentage.

In 1916 the Government of India called for report from experienced local irrigation and revenue officers regarding the prevalence of *kalar* or alkali in Sind, and the following is a resumé of their opinions :—

Mr. H. C. Mules, Collector of Karachi :—

" In former days grants of *kalar* land were made on very easy terms with a view to their reclamation. They were thoroughly washed, *i.e.*, flooded, and the water held on them by ' bund ' for a year or two, then rice was grown. The finest rice lands in Sind, producing a quality of rice known far beyond the boundaries of the province, are known as the ' mail ' in the Larkana District, near Gogharo. These lands were formerly rank bad *kalar*. Some very bad *kalar* lands were granted many years ago on a reclamation lease to the late Seth Ramchand of Khorewah, a very enterprising zemindar who in course of time obtained excellent results. There are concrete instances but the same kind of thing is going on all over the country on varying scale.

" A very striking instance of the movement of subsoil salt induced by the action of irrigation channels or floods is to be seen at Jacobabad. For one who remembers Jacobabad in the early seventies the change is very remarkable. Then the land in cantonments was sweet, the wells were sweet and the water good, the gardens were remarkable for their luxuriant growth and the vegetables raised therein were every bit as good as the best English vegetables. Now the whole place is salt, the wells are many of them useless, and the gardens have died away. But you have only to ride beyond the limits from which floods were excluded to find the lands which were flooded, washed and subsequently irrigated,

* This chapter is reproduced from the *Bombay Department of Agriculture Bull, No. 64 of 1914.*

bearing splendid crops. And I may say that hundreds of villages have been similarly affected. It is quite common to find the village site rank *kalar* and the surrounding fields sweet and productive.

"It will, I think, be found that the way to eradicate salts is to wash them out. Wherever there is good head of water and a reliable supply this is possible. But, of course, it is essential to drain off the water used for the washing; take the instance of 'puncho' water. It is by no means uncommon to hear officers speak of this system of passing off water after it has stood on the rice for a little while as a waste of water. It is not so; the cultivators know perfectly well that the water gets sour and must be passed away before it becomes so and injures the crop. Therefore depressions and low grounds are used for the reception of 'puncho pani', and the crops receive constant fresh supplies. In the same way it is necessary to pass away and renew water used for washing the land."

Mr. G. E. Chatfield, Colonization Officer, Jamrao Canal:—

"Salt or *kalar* land is to be found in the Jamrao tract, as in the rest of Sind, in large quantities. The salts are of different kinds and have different effects, some being almost harmless and others noxious to cultivation, some easily soluble in water and others not so. Native cultivators call them by different names ('white,' 'red,' 'black' *kalar*) and have hazy knowledge of their effects.

"In the Jamrao tract there are large stretches of *kalar* lands, which are regarded as uncultivable. Much of this land would be cultivated were it 'flow', but owing to the tendency of *kalar* to seek the highest lands such large *kalar* patches are usually 'lift.' Besides these, there are small sporadic patches of *kalar* scattered over the whole tract, so closely that scarcely any village, however excellent the soil, is without them. From a comparison of the land which is under perennial irrigation with the surrounding land, I should say that these patches had always been there and that irrigation is not responsible for the appearance, though it increases their size. It is difficult to observe sporadic patches of this kind, but from the general complaints of cultivators as well as from what I have actually observed in certain parts of the tract (*e.g.*, near Mirpurkhas and in Dehs 87, 88, 89), it seems that in many places *kalar* is spreading with irrigation (percolation, on the other hand, brings up *kalar* where none was previously found, and the land on either side of the canal minor and water course is almost invariably rank *kalar* for a considerable distance). Against this I must add that in many villages the *kalar* is certainly being washed down out of the soil by means of irrigation.

"In comparing Jamrao lands with those on inundation canals it must be remembered that the latter are generally lift lands or rice lands:

for when the Sindhi can get flow he will generally grow rice. In rice lands *kalar* is a matter of small importance, and in lift villages the water is generally sufficient for a mere fraction of the whole area, which fact enables the zemindar to pick and choose his land. Villages on the Central Hyderabad canals contain many waste numbers which are not taken up on account of *kalar* but which would be taken up were these villages brought upon the Jamrao canal.

"About the causes of the appearance of *kalar* I have little to add. In lands which have never been under irrigation it is nearly always present, though in varying quantities, and with irrigation it sometimes increases and sometimes decreases according to the nature of the subsoil. The only remedy known in Sind is to wash down salt into the subsoil with heavy waterings. For this purpose it is usual to start with some crop which can stand a certain amount of *kalar*. The crop which is preferred is rice; some of the inferior millets (*e.g.*, *sao* *), wheat and *jambho* † are also grown in such cases.

"I cannot record any very brilliant successes in the reclamation of land on the Jamrao, though some lands have undoubtedly been improved by cultivation in Digri and Jamesabad.

"Rice is undoubtedly well suited to *kalar* lands and the heavy flooding which it requires improves the land immensely. This crop is forbidden in the Jamrao and could not be permitted without a great loss of revenue. Neither is it a remedy suited otherwise to the tract; for while heavy flooding sweetens the land flooded it causes the salt to rise in the adjacent lands. Moreover, the worse stretches of *kalar* are usually too high for flow irrigation.

"In rice districts, such as the south of Hyderabad, of which I had formerly charge, it is only the worse kind of *kalar* which is regarded as uncultivable. But where much salt was present in the soil it was found necessary to change the water very frequently. This was effected by letting out the water from the cultivation into the ditches and depressions which surrounded the fields; unless this was done frequently the crop was believed to suffer.

"Much land on the Jamrao is undoubtedly deteriorating under irrigation and becoming *kalar*. Much land has not been taken up because it contains *kalar*. Much that has been taken up is not paying for the same reason. The recent rise of cultivation on the Jamrao is chiefly due to the giving out of fresh lands in 1905, and in any case would scarcely affect the question."

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* *Panicum Crus-galli.* † *Eruca sativa*

Mr. G. McC. Harrison, Superintending Engineer, Indus Left Bank Division :—

"There appear to be three kinds of alkali known in Sind :—

"I. *Rapri kalar*, or chloride of sodium, from which salt was manufactured before for use in Sind. Oil-seeds will grow on lands infiltrated by this kind of alkali.

"II. *Bhanothi kalar*. This is generally found where old village sites once stood, or where leaves and other debris decay. This is probably sulphate of sodium from which Glauber's salt was once manufactured near Sehwan old fort. Such *kalar* is collected and used as manure for crops. Its area is insignificant.

"III. *Dudh kalar*, or carbonate of sodium, is seen in arid high level lands. Rice can be grown on these lands if there is plenty of water."

It would undoubtedly be of the greatest use if an alkali map of Sind were prepared. In the tract of the proposed Rohri-Hyderabad canal such a map will be extremely useful; here there are no doubt isolated portions of land which owing to alkali are useless for any or only rice cultivation. In such portions minor canals or distributaries could be left out altogether or designed for rice cultivation.

Mr. F. St. J. Gebbie, Executive Engineer, Jamrao Canal :—

"For some years past there have been vague complaints that owing to the evil qualities of the Jamrao water all the land is turning to *kalar*. I have asked many zemindars to show me land which, before the Jamrao was constructed, had no *kalar* in it and which has now become unculturable, but no one has yet done so.

"It is true that there is now a much larger area of *kalar* land in the Jamrao tract than there was before the canal was constructed; but that is due to the large area of what was formerly waste and is now being cultivated. A good deal of this waste land was *kalar*, but the *kalar* did not become visible till it was irrigated.

"I know of no remedy for *kalar* except careful cultivation and manuring. I have heard a great deal of growing rice to wash out the *kalar* but I have still to see a case in which this has been done and any other crop except rice grown on the land afterwards. The Sindhi in these parts is a great believer in this system; but it seems to me he makes such a strong point of it rather to try and get permission to grow rice than with any idea of really washing the *kalar* out of the land. All Sindhis are anxious to grow rice because it suits their lazy slipshod methods of cultivation.

"Provided that the people are satisfied with the supply of water as fixed by Government, *viz.*, one cusec for every 300 gross acres, there is no objection to allowing them to grow rice on the Jamrao; but they

will not be satisfied with this. They say that rice wants a constant supply and they cannot be given this under existing conditions. With the outlets and water courses as they are, the only efficient method of distributing water fairly to every one in a village is by 'share lists' as is done in the Punjab. But if any man is to get water constantly a share list cannot be prepared and he must get water at the expense of other cultivators in the village.

"Since the Jamrao was constructed about 57 per cent. of the culturable area of village No. 18 has been cultivated annually and practically all by flow; but no *kalar* has appeared because there never was any in the soil. On the other hand, village No. 38, in which about 20 per cent. area is cultivated all on lift, is beginning to show *kalar* in many places."

In summing up the Commissioner in Sind stated:—

"The reports submitted scarcely give an adequate idea of its extensive prevalence throughout the province, owing to the non-existence of any statistics on the subject. Even materials for a rough estimate of any degree of reliability are not available. It is hardly possible to say more than that the occurrence of saline area, in every gradation from isolated patches to continuous barren tract many miles in extent, is one of the most familiar features in Sind; and the gravity of the evil is to be measured, not only by the diminution in the cultivated area and the injury to crops occasioned in localities where attempts are being made to control it, but also the permanent exclusion from cultivation of large areas of otherwise valuable lands."

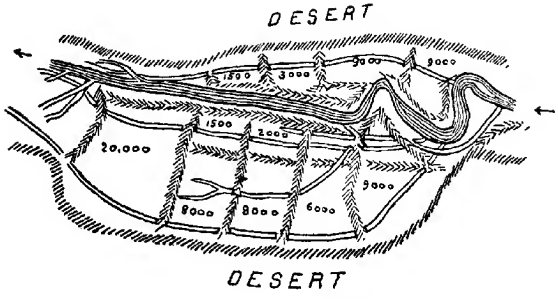
CHAPTER III.

Reclamation Work in Egypt.

Egypt with a cultivated area of about 6 million acres and with a population the density of which is one per acre, is only a fraction of the size of an Indian province. As the land is very productive, the agriculture and irrigation afford most useful study for the irrigated portions of North-Western India.

Formerly only the basin system of irrigation was practised in Egypt. This method consists of flooding the land in the basins to a depth of several feet at High Nile about the second week in August, and then when the river level sinks in October in letting the water back into the river.

The plan shows clearly a system of basins with the channels to fill and empty and the 'bunds' necessary. When the water is emptied the greatest care is used to prevent too rapid an escape which would scour out the new silt deposited.



A system of basins in Upper Egypt.
The figures show the area in acres of the different fields composing the system.

C P

With the basin system only one crop can be taken per year and cotton cultivation is not possible. When the basin system was practised there was no damage from alkali. The large amounts of water used washed the salts well down into the subsoil.

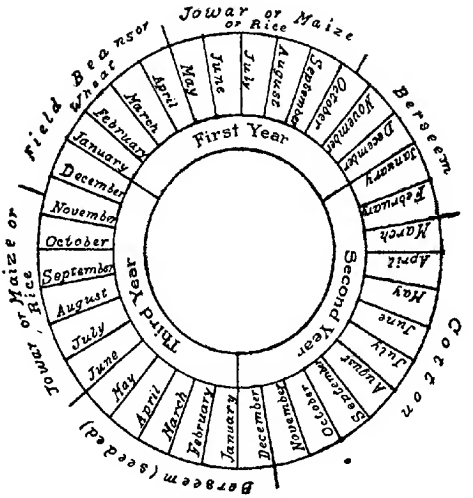
Damage from alkali began to be felt when perennial irrigation canals were substituted for the basins, but as a rule this was chiefly experienced in the low lands in the north along the borders of the Mediterranean. Land which is under the 6-foot contour line is apt to show signs of salt more especially along the large drains which run full at the time of high river. The northern land gradually tails into the great lakes, Lake Edkou, Lake Burlos and Lake Menzaleh, which lie between Alexandria and Port Said. These lakes communicate with the sea and the bordering land gets flooded with sea water especially during northerly winds.

Lake Aboukir, one of the smallest of these lakes, has been reclaimed and as most of the reclamation work in Egypt is similar in character, a study of the history and methods of the work is of interest.

The other lakes represent an area of over a million acres. When this area is taken in hand after provision is made for the necessary irrigation water by works in the upper sources of the Nile, a tract of excellent cotton and general agricultural land will become productive. This work would be an excellent field for the new Empire Development Board. The agricultural population of Egypt would rapidly take up the land when in a fit state at very remunerative prices. There is no harder working and painstaking agriculturist than the Egyptian "Fellah" when he is working on his own land and for himself.

The high production of agricultural land in Egypt is remarkable, crop succeeds crop and there are no fallows. Yields of seed cotton of 2,000 lb. per acre are nothing remarkable. A rough method of estimating the return of agricultural land used to be to multiply the average yield of the land in 'kantars' (say 315 lb.) of seed cotton by £15. There is land averaging up to 10 kantars which thus would be worth £150 per acre.

An example of cropping of good agricultural land spread over 3 years is as follows:—



Typical 3-year rotation.

It will only be by the adoption of suitable intensive rotations and the largely increased use of leguminous fodder crops and keeping and feeding increased number of live stock that the yields of irrigated land in North-West India will approximate more nearly to those in Egypt. At present the average yields per acre in the Punjab canal colonies, especially on the older colonies, are very small and evidence seems to point to the fact that yields are decreasing. The various Agricultural Departments have taken the matter up seriously and their recommendations together with the necessary co-operation of the Irrigation Department will have effect in time. The Board of Agriculture in 1917 recommended combined action for the different provinces affected by means of a central research station, and this would be the best solution of the matter which is of the greatest importance from every point of view.

CHAPTER IV.

Aboukir Company's Reclamation Work.

The reclamation of Lake Aboukir was started by an English Company in 1888. Some 30,000 acres were taken up on the site of the lake of that name about 10 miles from Alexandria. The land was a dry salt plain in the hot weather and a shallow salt lake in winter. As the soil was a sticky black clay and seemingly very impervious to water many doubted the feasibility of the reclamation. The percentage of soluble salt in the first three feet averaged over 6 per cent.

The first step was the provision of a sea-wall to prevent any sea water from flooding the land, especially during the period when northern winds blow across the Mediterranean.

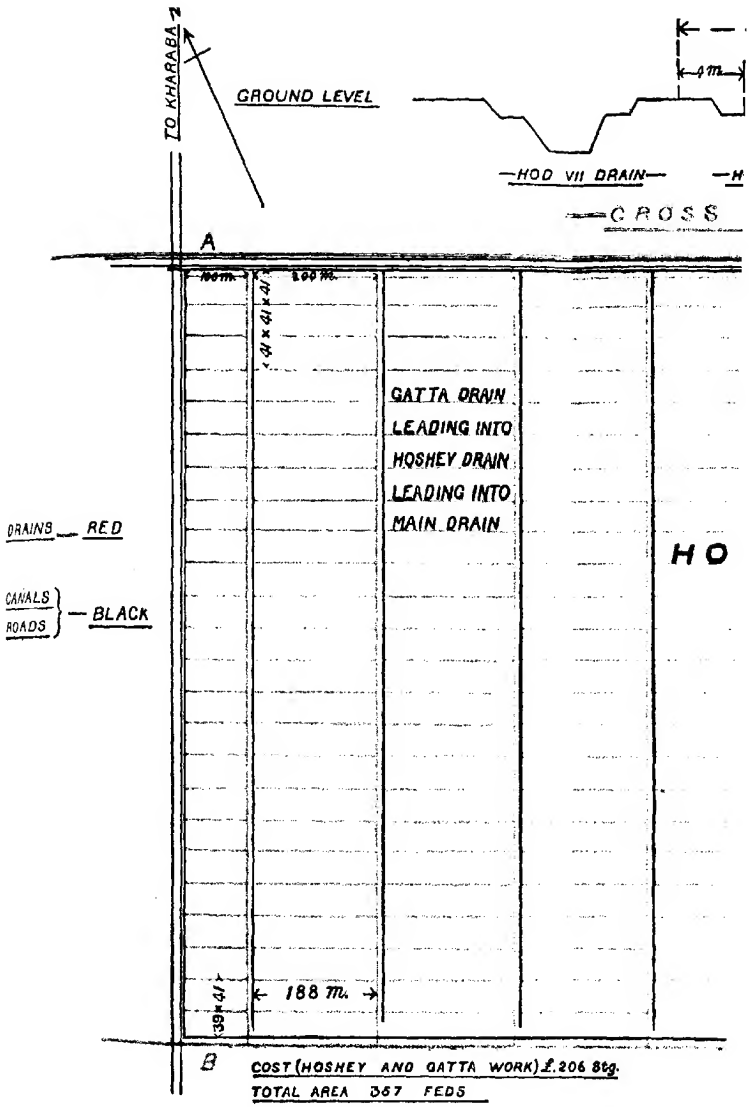
Then the canalization was taken in hand. The main drains and canals were dug and the minor earth-work completed for those blocks which were first started. The land being below sea level the drainage water had to be pumped up into the sea. The object was to keep the subsoil water level at a minimum depth of 2′ 6″ below surface level. The main drains had to be of sufficient depth to get a flow from the minor drains.

The Company had many difficulties at first, and it was only after years of experience that the technique was perfected and reliable methods standardized that the reclamation work became successful and the Company enabled to pay large dividends which it has done ever since.

The drainage pumps gave difficulty at first; the pumps at the ends of the main drains would suck dry before the water in the minor drains has begun to flow. This difficulty was got over by the provision of drainage outlets into Lake Mariotics the level of which was kept down by a Government pump installation to 8 feet below sea level to provide drainage for the surrounding country.

The 'gatta' or plot of 2 feddans (1 feddan=about 1 acre) is the unit of canalization. The series of plots is the 'hoshey' and the 'hosheys' make up the 'hod' or village. Each 'hod' is treated separately for labour, management and account purposes. Each 'hod' has a foreman or 'holi' responsible for all matters in the 'hod' and an 'esbah' or village is built in a convenient site. This 'esbah' is usually stone built and contains 'magazines' or stores, court for cattle and workmen's rooms and threshing floor.

The plan and section of a typical 'hod' is attached and clearly shows the principles of the canalization.



COST (HOSHEY AND GATTA WORK) £.206 Stg.
TOTAL AREA 367 FEDS
GATTA AREA 360 ,,
LOSS ON ROADS
CANALS OR DRAINS } — 7 FEDS
APPROX. SCALE 1 : 5000
EACH GATTA = 2 FEDS (42 × 200M) GROSS

The first work after the earth-work is finished is levelling. This is done by wooden scoops working after ploughs. It is very important work and the plots must be made quite level. Permanent bunds may be made in the centre of the plots if there is much difference in level between the two ends. Levelling must be carefully supervised. There is no operation in which more money can be wasted. These scoops or 'khasibehas' have been described in Pusa Bulletin No. 73 on "New Agricultural Implements for India."

As the cost of levelling varies with the square of the distance of the 'lead,' short leads should be the rule.

After levelling water is let into the plots and the final levelling given by a long board drawn by cattle through the water.

Water is only allowed for flooding purposes during high Nile. It is however essential that while washing the plots should be kept full, *i.e.*, 3-4" deep. If the plots are simply irrigated and then allowed to dry they get worse than they were before, owing to evaporation. If the plots are kept properly full the salt on solution is washed into the sub-soil and goes off by the drains. There is no surface washing and any case of broken bunds by which water can get direct into the drains is strictly against rules. Also each plot has a separate inlet for the irrigation water and no plot receives water from another plot. After washing for a couple of seasons the plots begin to sweeten up. It is however sometimes necessary to run a drain up the middle of each plot if the improvement is slow. The first crop sown is 'dencbah' (*Panicum Crus-galli*) which is an useful fodder. When the land can grow really good berseem (*Trifolium alexandrinum*) the cultivators will buy or rent it eagerly.

Some of the land is sold to the actual cultivators on ten yearly instalments. The instalments are calculated to be equal to the value of the yearly cotton yield. The cultivator has the other crops to live on in the meantime, and as he eventually becomes the owner of his land the system is satisfactory for both sides and works well in practice.

The above is only a brief outline of the work, it is in fact a highly specialized branch of estate management and requires a combination of agricultural and civil engineering.

The cost of the reclamation work depends on special circumstances; it may vary from £5 to £15 per acre.

Typical analyses of the soil are appended. It may be noted that all observers dwell on the fact that the soil in actual practice is much more pervious to water than would be supposed by the mechanical analysis.

There are a number of other reclamation works on much the same principles, they have not all been successful; there is the Kom-el-Akhdar concern on which a French Company is said to have spent a

million pounds on 10,000 acres without achieving success. The soil was not different from others which have been successfully reclaimed. It is probable the failure was due to Western methods being adopted without modifications necessary to the East.

Considerable expectations were based on tile drainage for reclamation in Egypt but only small works have been carried out so far. The advantages of this method are the speed and thoroughness with which the work can be completed and the saving of actual land.

The disadvantages are the cost and the fact that the salt gradually destroys the tiles. There is also the danger of the washing water getting direct entrance to the drains through cracks and holes which would cause great damage. The saving of land is more apparent than real as after the land is reclaimed many of the drains can be filled in.

A point of great practical importance is that the land should be properly reclaimed before it is given out to cultivators. If the salts are not properly washed down into the subsoil before ordinary crops are grown the only result is loss to all concerned.

Analyses of soils from Lake Aboukir, made by Breazeale of the American Bureau of Soils, from the United States Department of Agriculture, Bureau of Soils Bulletin 21 :—

Constituent	7544, 0 to 12 inches	7545, 12 to 24 inches	7546, 24 to 36 inches	7538, 0 to 6 inches	7539, 0 to 12 inches	7540, 0 to 6 inches	7541, 6 to 12 inches	7,542, 0 to 6 inches	7543, 6 to 12 inches
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Ions :—									
Calcium (Ca) . .	15·45	2·66	1·44	13·16	10·12	17·18	9·72	9·16	[illegible]
Magnesium (Mg) .	Tr.	Tr.	Tr.	Tr.	3·73	Tr.	11·87	Tr.	Tr.
Sodium (Na) . .	17·03	33·18	34·62	15·35	15·17	7·73	6·37	18·34	27·91
Potassium (K) . .	1·65	2·48	2·61	4·82	4·61	8·24	3·59	5·89	6·49
Sulphuric acid (SO_4) .	34·65	12·32	8·78	46·54	32·07	53·62	7·98	41·27	41·58
Chlorine (Cl) . .	30·06	48·41	50·79	14·17	30·11	6·01	57·51	12·24	7·38
Bicarbonic acid (HCO_3)	0·56	0·93	1·86	5·66	3·29	7·22	2·06	13·10	13·84
Conventional combinations :—									
Calcium sulphate ($CaSO_4$)	49·19	9·12	4·89	45·68	34·30	58·25	11·29	31·00	..
Calcium chloride ($CaCl_2$)	2·77	..	..	..	..	..	17·70	..	..
Magnesium sulphate ($MgSO_4$).	..	..	..	..	10·98	..	..	..	..
Magnesium chloride ($MgCl_2$).		..	..	..	5·93	..	46·54	..	..
Potassium chloride (KCl).	3·13	4·72	4·96	0·23	8·79	12·54	0·86	11·14	11·52
Potassium bicarbonate ($KHCO_3$).	..	..	..	..	..	4·30	..	..	..
Sodium chloride (NaCl)	44·23	76·18	79·71	16·17	35·50	..	13·57	11·36	3·52
Sodium sulphate (Na_2SO_4).	..	8·70	7·89	21·13	..	18·56	..	28·60	65·98
Sodium bicarbonate ($NaHCO_3$).	0·77	1·28	2·55	7·79	4·50	6·35	3·98	17·90	18·48
Per cent soluble .	10·54	0·01	5·80	1·69	1·82	1·16	4·11	0·92	1·17

The following table gives the results of mechanical analyses of samples of soils collected in Egypt:—

Number	Locality	Description	Organic matter	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0·5 mm.	Medium sand, 0·5 to 0·25 mm.	Fine sand, 0·25 to 0·1 mm.	Very fine sand, 0·1 to 0·05 mm.	Silt, 0·05 to 0·005 mm.	Clay, 0·005 to 0·0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
7538	Aboukir tract .	Loam, 0 to 6 inches	0·65	0·52	0·40	0·38	18·42	35·06	28·46	16·16
7539	Do. .	Loam, 0 to 12 inches.	0·50	0·02	0·08	0·16	23·34	42·68	21·00	12·52
7544	Do. .	Clay loam, 0 to 12 inches.	0·80	0·14	0·30	0·18	2·32	4·14	35·08	57·44
7545	Do. .	Clay loam, 12 to 24 inches.	0·69	0·00	0·10	0·06	3·86	15·80	30·72	49·30
7546	Do. .	Clay loam, 24 to 36 inches.	1·04	0·00	0·04	0·04	0·92	5·76	51·28	41·64
7540	Do. .	Clay loam, 0 to 6 inches.	0·29	0·46	0·68	0·42	6·26	8·26	31·40	51·08
7541	Do. .	Clay loam, 6 to 12 inches.	0·41	0·20	0·28	0·32	3·52	5·42	37·30	52·48
7542	Do. .	Clay loam, 0 to 6 inches.	0·24	0·30	0·42	0·36	3·68	9·48	28·28	57·02
7543	Do. .	Clay loam, 6 to 12 inches.	0·83	0·20	0·56	0·24	1·76	8·74	25·76	62·62
7555	Kom-el-Akhdar	Clay loam, 0 to 12 inches.	0·45	1·84	5·80	4·20	21·04	15·84	7·48	42·10
7556	Damru . .	Clay, 0 to 12 inches	2·46	0·60	0·88	0·20	0·58	4·98	37·08	55·46

CHAPTER V.

Reclamation Work in India.

The reclamation works in India best known to the writer are those of Dr. Leather and Mr. Barnes and the Daulatpur reclamation station in Sind.

Dr. Leather analysed a large number of salt samples and mapped areas of salt lands in canal areas of the United Provinces. The results are published in a United Provinces Government blue book[1]. The late Mr. J. Hector Barnes[2] reclaimed a plot of salt land near Lyallpur in the Punjab and did a considerable amount of laboratory work in connection with it.

The history of the Daulatpur reclamation station is fully described in Bulletin 64 of the Department of Agriculture, Bombay (1914). This station consisted of 400 acres of light salt land. The reclamation work was not carried out so far as it might have been, but it was conclusively proved that the Egyptian methods were applicable to Sind. The difficulty in carrying out this work to a conclusion was that till the Indus Barrage is completed there is only enough irrigation water for the good land. So having proved the fact that reclamation on standard lines presented no difficulty the Sind Agricultural Department had to switch on to more urgent work.

When the Indus Barrage and the new system of canals is completed, say, within the next 15 years or so, reclamation work will have to receive attention again.

[1] Leather, J. W. "Investigations on *Usar* Land in the United Provinces."
[2] Barnes and Barkat Ali. "Alkali soils: Some biochemical factors in their reclamation." *Agric. Journ. Ind.*, Vol. XII, p. 368.

Analysis of Daulatpur soils

Salt	Square 64		Square 66		Square 68		Square 3		Square 5	
	Surface	2′ down	Surface	2′ down	Surface	2′ down	Surface	2′ down	Surface	2′ down
Sodium carbonate	...	...	...	...	...	...	...	...	...	0·00526
,, bicarbonate	0·0167	0·02500	0·0375	0·03750	0·03750	0·04170	0·0292	0·0334	0·02500	0·02920
,, sulphate	...	...	...	0·17920	...	...	...	0·0450	...	...
,, chloride	...	0·28380	1·22900	0·91340	0·26350	1·09400	0·0753	0·0548	0·22840	1·09200
Magnesium sulphate	...	0·10270	...	0·08110	0·00600	0·05250	...	0·0595	...	0·07570
,, chloride	0·0342	...	0·09840	...	0·05514	0·09110	0·0385	...	0·06420	0·06130
Potassium sulphate	...	...	...	0·01256	...	...	...	0·0161	...	...
,, chloride	...	0·01075	0·00768	...	0·00461	0·01379	0·0199	...	0·01690	0·01070
Calcium sulphate	0·0175	0·25160	0·05250	0·12920	0·17690	0·11560	0·1196	0·0884	0·00875	0·03400
,, chloride	0·0356	...	0·12350	...	...	...	0·0134	...	0·04830	...
Total soluble alkali	0·1040	0·67385	1·54858	1·35296	0·54365	1·40869	0·2959	0·2972	0·39155	1·29816

Salt	Square 7		Square 24		Square 26		Square 28	
	Surface	2′ down	Surface	2′ down	Surface	2′ down	Surface	2′ down
Sodium carbonate	...	0·00343	...	...	...	...	...	...
,, bicarbonate	0·02500	0·03540	0·02086	0·02920	0·02086	0·02919	0·02919	0·02919
,, sulphate	0·59390	0·11790	...	...	...	...	...	0·20040
,, chloride	1·03500	0·33490	0·29710	0·43990	3·06100	0·92180	0·78200	0·48710
Magnesium sulphate	0·11350	0·12970	...	...	...	...	0·04140	0·09390
,, chloride	...	...	0·14970	0·18400	0·32080	0·12830	0·04853	...
Potassium sulphate	0·00538	0·00359	...	...	...	...	...	0·01436
,, chloride	...	...	0·00614	0·00614	0·01689	0·01353	0·01382	...
Calcium sulphate	0·23120	0·02041	0·35280	0·29750	0·35870	0·03500	0·20400	0·22090
,, chloride	...	...	0·11710	0·05700	0·22890	0·12120	...	...
Total soluble alkali	2·00398	0·64533	0·94370	1·01374	4·00715	1·24902	1·11894	1·04585

CHAPTER VI.

Conclusions.

The following are the opinions of the writer in regard to salt land reclamation work in India :—

1. Methods successfully adopted in Egypt are suitable for North-West India.
2. Washing the salt into the subsoil is the only effective method of dealing with the problem.
3. Surface washing and running the salt-impregnated water off periodically is a wasteful and unsatisfactory method except under very special circumstances.
4. In North-West India owing to the depth of the subsoil water, the drainage problems are simple and this generally renders the whole reclamation problem much easier of solution. The field drains are necessary to form units for levelling but the system of main drains is in the meantime unnecessary. Drains fill from beneath, and they will remain empty so long as the water can get down to the low subsoil level.
5. Careful levelling is essential. The small drains are useful to mark off the plots and to provide earth for the bunds. Water should be taken direct to each plot. It should never be fed from plot to plot, and while washing the plots should be kept full.
6. After washing the physical texture of the soil must be improved by suitable cropping; this is done in practice most easily by feeding cattle on the land on leguminous fodder crops.

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